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# A Method for the Determination of Vapor Composition

Chemical Engineering

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# A METHOD FOR THE DETERMINATION OF VAPOR COMPOSITION

BY

WILLIAM SIDNEY FORD

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THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CHEMICAL ENGINEERING

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COLLEGE OF SCIENCE

UNIVERSITY OF ILLINOIS

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May 31 1907.

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

William Sidney Ford

ENTITLED A Method for the Determination of Vapor Composition.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science

in Chemical Engineering.

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Chemical literature abounds with data of the vapor pressure and the boiling points of mixtures of a large number of liquids, but the cases in which the compostion of the vapor in equilibrium with the liquid phase has been determined are few. In commenting upon this Carveth (1) says, "The truth of this statement is supported by the paucity of cases in chemical literature where there has been determined with any degree of accuracy, the composition of the liquid and vapor in equilibrium at any pressure whatever, while the cases exemplifying separations carried out under the ordinary conditions of laboratory or actual technical work,have (so far as the writer is aware), not been attacked at all". This neglect cannot be due to a lack of appreciation of the importance of this subject, for in techincal work fractional distillation is a most important factor. In practice certain results may be approximately attained by certain usages, but concerning the laws governing these separations there is but little known. Interesting questions arise, therefore, concerning the nature of these laws. Just what is the effect of a small amount of impurity upon the separation of two liquids? If two liquids be difficult of separation, cannot their separation be simplified by the introduction of a third non-volatile component? The variation of partial pressures may be known by knowing the composition of the vapor. Further, the development of that part of the Phase Rule dealing with mixtures of two consulate liquids is

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based upon the above line of work.. The importance of such work and the scope of the field are, therefore, great.

There have been a number of attempts made to separate the liquid and vapor phases of boiling liquids and analyze them, some of the more prominent of which are given below.

In 1879 and 1881 Brown (*II*) investigated the operation of dephlegmators and worked out the law of the compostion of the distillate when the still-head is kept at a constant temperature.

Lehfeldt (IV) in 1898 determined vapor composition by means of an apparatus represented in Figure I. The liquid was boiled in the vessel (A) immersed in a bath which was heated externally. The temperature of both the bath and liquid were determined. The vapor was collected in a receiver (D) which was in turn connected with a manometer and a vacuum pump. By means of the incandescent light (L) covered with a cloth, the condenser tube near the flask was kept at a temperature above that of the boiling liquid. The analysis of the liquid and the vapor was made by the use of a Pulfrich refractometer. Lehfeldt says that some of the condensed vapor clings to the side tube and it is not certain that what is collected in the receiver represents a fair sample. The results represented by portions of the curves near the ends are considered by him as somewhat doubtful.

A. E. Taylor (V) used an apparatus very similar to the one just described. ( See Figure II.) His boiling flask (A) contained an amount of platinum tetrahedra approximately equal to the volume of the liquid used. The neck of the flask and the vapor delivery tube were heated by an electric wire. A boiling point

curve was employed for analyzing the liquid and the vapor. In regard to errors present, Taylor says (VI) that in the boiling point methods an accuracy of plus or minus one per cent. is about all that can be hoped for.

J. V. Zawidski (VII) used a somewhat elaborate apparatus for the determination of vapor pressure and vapor composition. Mixtures were distilled at a fixed temperature by adjusting the pressure; the composition of the distillate was determined by finding its index of refraction and from this the partial pressures of the components of the boiling liquids were determined. Boiling was brought about by an electrically heated platinum wire in the liquid. Marshall (VIII) says that Zawidski's method requires a considerable amount of special apparatus to avoid certain sources of error and that many of his results are inaccurate owing to the in troduction of other complications.

Scheinemakers (IX) has determined the vapor composition in the system--phenol and water--by a simple distillation. His results are not considered by Bancroft (X) to be very accurate.

The boiling point and vapor composition curves of mixtures of benzene and acetone have been worked out by M. R. Ebersole (XI). The mixture was boiled under atmospheric pressure by heating the flask in a water bath, garnets being used to prevent super-heating. The neck of the flask andthe adjacent portion of the condenser were electrically heated. The composition of the liquid was found from the boiling point curve, and that of the vapor from its specific gravity. It has been shown by Taylor (V) that even with the use of platinum tetrahedra and the exercise of the greatestcare, it is

almost impossible to obtain accurate results.by the boiling point method of analysis. Further, since in the flat part of the curve a small variation ~~at a~~ of the boiling point corresponds to a relatively large change in composition, it would appear that Ebersole's results are least accurate where accuracy is most desired.

Perhaps the best method for working in vapor composition is that described by H. C. Carveth ( I ) in his second paper on "Vapor Composition Studies". His apparatus is shown in Figure III. A balloon flask carries the condenser (C), a thermometer (T) dipping into the liquid, and a glass tube (L) blown to a bulb (B) supported just above the mixture in the flask. Part of the vapor is condensed and returned to the bulb where it is boiled. From the boiling point of the liquid and the vapor the composition of each is determined. He claims an accuracy within one per cent. which he says is just as accurate as having the still-head heated with a wire. Carveth claims the following points for his method:

(1) Accuracy within reasonable limits.

(2) Ease of manipulation.

(3) Can determine change of partial pressure with the introduction of a non-volatile salt.

It is apparent from what has been stated that there are certain difficulties attending vapor composition study, chief among which is the separation of a sample of the vapor from the liquid being distilled. Then, too, in the boiling point method employed in analyzing the boiling mixture as well as the vapor, there is usually some doubt as to the accuracy of the results because of the effect of superheating, and the small quantity of vapor which may be collected. The method of Zawidski introduces many complications,

and that of Brown is no more accurate. The need, therefore, of a method combining simplicity and accuracy is very evident.

The method herein presented appears to meet these requirements. By this method, samples of the liquid and vapor may be taken almost simultaneously and analyzed by a suitable method. There is no evidence of super-heating and the manipulation is simple. A detailed description will now be given.

## Experimental Part.

By employing an apparatus similar to that used by Berthelot for the determination of latent heats (XIII) and modified by Professor Kahlenberg (XIV), it seemed possible to eliminate some of the difficulties met with in previous determinations of vapor composition. The forms of apparatus designed by them are shown in Figures IV and V respectively. By using a boiling flask of this form, with a condenser passing down through the boiling liquid, it was thought that the vapor which was in equilibrium could be more readily removed. Then, too, it would be more apt to have the right composition, as undue condensation would not take place. With this in view, the general form of apparatus shown in Figure VI was constructed.

The apparatus consists of the outer largertube (1) sealed to a short piece of glass tubing (2) of such size as to admit a tube (3), 1.7 cm. in diameter, which serves as a condenser. These are held together by the rubber tubing (4). The condenser tube is sealed at the top and has the openings (5) in the side for

admitting the vapor. The cork stopper (6) carries a thermometer, graduated to tenths, by means of which the temperature of the boiling liquid is determined; and two tubes (7) containing leads for making connections with the platinum wire (8) by means of which the solution is heated. By placing a small thermometer, graduated to fifths, in the inner condenser tube, the temperature of the vapor could readily be ascertained. To prevent the boiling liquid attacking the rubber connecting the outer tube and the condenser, sufficient mercury was poured in to well cover the joint.

To test the efficiency of the apparatus, pure acetone was employed. When the apparatus was not insulated from currents of air much vapor condensed in the upper part as might be expected. In order to prevent this it was wrapped with asbestos, but this did not prove sufficient. When wrapped with hair-felt the apparatus worked well, just so long as no part of the tube was exposed, but a few minutes after making an opening to read the temperatures, condensed vapor ran down the walls. The whole apparatus was then enclosed in a magnesia cylinder such as used around steam pipes. The ends were closed and glass windows were provided in the side for reading the temperature.

With acetone in the vessel boiling freely, temperature readings were taken every two minutes for a period of one and one-half hours, and it was found that the temperature of the liquid and of the vapor remained constant, never varying more than one-tenth of a degree, and usually less than five-hundredths. This indicated the absence of outside influences and super-heating. From this experiment it was very apparent that to insure accurate determina-

tions of the vapor composition there was needed an insulating jacket that could be conveniently manipulated, and a method of removing samples of the boiling liquid for analysis. To accomplish this, the apparatus was finally arranged as shown in tha accompanying photograph.

The insulator consists of a wooden box lined with hair-felt an inch thick, and provided with a glass door in front which enables the temperature to be conveniently read, and gives ready access to the interior.

The vapor receiver shown in Figure VII was made from an adapter by sealing on two stop-cocks (A) and (B). One is for the purpose of removing the condensed vapor, the other for connection with the manometer. The receiver is cooled by tap water circulated through the gum tubing wrapped around its walls, as shown in the photograph.

In order to remove samples of the liquid for analysis, a funnel tube long enough to dip into the boiling mixture is run through the cork. (See Figure VIII). Through this tube a capillary is introduced reaching to the bottom. The upper end is bent as shown, and connected at (A) with a pycnometer which in turn is attached through the tube (D) to a suction-pump.

To test the apparatus some Kahlbaum's thiophene-free benzene was boiled in it. The temperatures of the liquid and vapor were read at intervals of five minutes for a period of two hours and twenty minutes. It is seen from the accompanying curve that both temperatures were practically constant and equal. This indicates at least uniform conditions.

The liquids chosen for investigation were benzene and acetone, since they are easily obtained pure, and since their boiling point curve is a normal one. Also, Ebersole has worked on this system and his data should give opportunity for comparison. The benzene used was Kahlbuam's thiophen-free boiling at 79.6 under 740 mm. pressure. It was not redistilled, but used directly from the bottle. Kahlbaum's acetone was used. This stood two months over calcium chloride and was then distilled from a large flask using a Glinsky tube. The first and last portions were discarded. The distillate had a boiling point of 55.8 C. under 740 m.m. pressure.

For the purpose of analysis of the mixtures it was planned to use the relation between the composition and specific gravity. For this purpose two Saunder's pycnometers of the form shown in Figure IX were made. To one end of a five cubic centimeter pipette is sealed a stop-cock and to the other, the graduated part of another pipette, reading directly to hundredths of a cubic centimeter. To the latter is sealed a capillary closed by a ground-glass cap. These pycnometers were calibrated by filling to a known mark with mercury at a definite temperature, and weighing. The volume could then be calculated from a specific gravity table. The method of analysis by specific gravity is accurate, but it was found to involve much workand calculation, making it impossible to collect any considerable amount of data in the time available.

The composition of mixtures determined by the specific gravity method was checked by the index of refraction method. The latter was found to be so much more convenient that it was employed as

the method of analysis of the vapor and the boiling liquid. A number of mixtures of known composition by weight were prepared and their indices of refraction determined by means of the Abbé refractometer. Two readings of duplicates of each sample were always taken and the mean of the four readings chosen. These practically always checked to 0.0005 and usually to 0.0001. The temperature of the prism of the instrument was kept at 25° by circulating water around it from a constant temperature bath. From the data thus obtained, there was plotted a percentage composition-index refraction curve represented on page 29 . Knowing the index of refraction of any mixture, the composition could be read directly from the curve. Table XI shows roughly the effect of variations in temperature upon the indices of refraction of acetone, benzene, and a mixture of the two. Since the temperature in the refractometer never varied more than 0.3° from 25° C it is seen that the error introduced from changes in the temperature is very slight. The readings of the refractometer were accurate to at least 0.0005. From the plotted composition-index of refraction curve values are obtainable which are accurate to about 0.4 per cent.

A determination of vapor composition was made as follows: The vessel was filled nearly to the holes of the condenser with the mixture of approximately the desired concentration, and a current of from five to ten amperes turned on. After the mixture had been boiling for some time, the temperatures of the boiling liquid and the vapor were recorded, and a sample of the mixture taken. After five minutes the temperatures were again read, a sample of the liquid mixture removed, and the condensed vapor run out of the

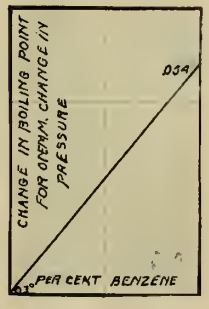
receiver. This method was continued until about eight sets of samples had been collected, by which time the liquid had fallen to the bulb of the large thermometer. For the next trial, a mixture differing slightly in composition from the first was used, and the process was repeated as above. Successive mixtures were employed until the whole range of the curve had been worked over, about eight different concentrations being employed.

The general behavior of the apparatus was very satisfactory. By keeping the heating coils at the same level, the liquid could be made to boil freely and uniformly, the thermometer showing no sign of super-heating. In taking samples of the mixture for analysis the liquid was removed by applying suction. When the pycnometer was full, it was disconnected from both the capillary and the pump, the liquid in the capillary siphoning back into the boiling vessel. The liquid in the pycnometer was removed to small weighing tubes, and the vapor phase thus reduced tothe minimum as these samples had to stand for several hours before the index of refraction could be determined. The capillary and pycnometer were dried by suction before being used again. Samples of the boiling mixture were always taken from near the center ~~of the column~~.

The data relative to the boiling point of the samples of mixtures of acetone and benzene, the index of refraction of the same and of the distillate from these, are incorporated in the Tables I - VIII. In the first column is given the number of the sample. $L_1$, $L_2$,.... refer to the first, second..... samples of liquid taken. $V_2$, $V_3$,.... refer to the samples of vapor run out of the receiver at the same time that $L_2$, and $L_3$,.... were taken

respectively. In column two are found the temperatures of the boiling mixtures at the time the liquid samples were taken. All temperature readings are referred to a standard thermometer. The third column contains the mean of the two successive boiling point readings, and the fourth the same corrected to 740 m.m. In the fifth column is found the temperature of the vapor read at the time of ~~the taking of~~ taking the sample of liquid, and in the sixth the mean of successive readings. From the index of refraction in column seven, the composition of the liquids and vapor given in the eighth is found by reference to the curve. The mean composition of two successive liquid samples, is given in the last.

The method of correcting the values for the boiling point of the mixtures as given in column three, for pressure, is only arbitrary. From Landolt and Bornstein's Tabellen, the correction for pure acetone for a change of one m.m. in pressure is 0.03° C., for benzene 0.054° C., and by plotting these values as shown in the curve below, the correction for any composition is found.




Tables IX, X and XI are self-explanatory.

The data in Tables I - VIII inclusive are shown graphically in the curve on page . Here the boiling point ~~of~~ and vapor composition curves are plotted in the usual manner with composition as

abscissas and the boiling points as ordinates. It is seen that the values for the boiling points are quite regular, giving a smooth boiling point curve which agrees with that obtained by Ebersole. (Ebersole's results are indicated by ×,×) The points for the vapor composition curve are not so regular. While they show the general direction of the curve, yet in each set of determinations, they tend in a vertical direction. This may be explained by the fact that, owing to the small amount of the liquid present in the boiling vessel, the change of composition is not uniform. As a result, the mean values for two successive liquid samples do not correspond to the sample of vapor collected for that period. This may be remedied by collecting samples at intervals shorter than those employed here. The points on the vapor curve do not agree very well with Ebersole's, especially near the end. He commented upon the "gathering" of the points in that portion of the curve where the per cent. of benzene is low. This is very noticeable from the data herein presented. The temperature of the vapor as represented by the red lines on page 17 seems to follow no definite law. It is nearly always below that of the liquid.

From the behavior of the apparatus, the following criticisms seem pertinent;

(1) The capacity is too small. The volume should be 500 or 600 c.c. To meet these requirements, a large flask may be employed, the vapor tube being fitted as in Berthelot's apparatus, Figure IV.

(2) The amount of condensing surface is proportionally large. The use of a largerflask and a smaller vapor tube will obviate this.

(3) Samples of the vapor should be taken nearer the surface of the liquid. It is possible to prevent the liquid particles being carried over by wrapping the holes in the vapor delivery tube with several thicknesses of fine platinum gauze.

(4) The insulating jacket should be more compact, and the interior kept warm by an incandescent light.

The composition-specific gravity and the composition-index of refraction curves on pages 27 and 29 are nearly straight, each having only a slight sag near the acetone end. On the former curve Ebersole's values are indicated by ✗ .

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In this paper there have been presented the following:-

(1) A brief summary of the previous methods for vapor composition study.

(2) A new form of apparatus for the separation of the vapor from the boiling mixtures, and the simultaneous removal of a sample of the liquid.

(3) A composition-boiling point curve for all mixtures of acetone and benzene at 740 m.m. pressure.

(4) A vapor-composition curve illustrating the composition of the vapor from all mixtures of acetone and benzene at their boiling point under 740 m.m. pressure.

(5) A composition-index of refraction curve for mixtures of acetone and benzene at 25° C.

(6) A composition-specific gravity curve giving the specific gravity at 25°/25° for all mixtures of the above liquids.

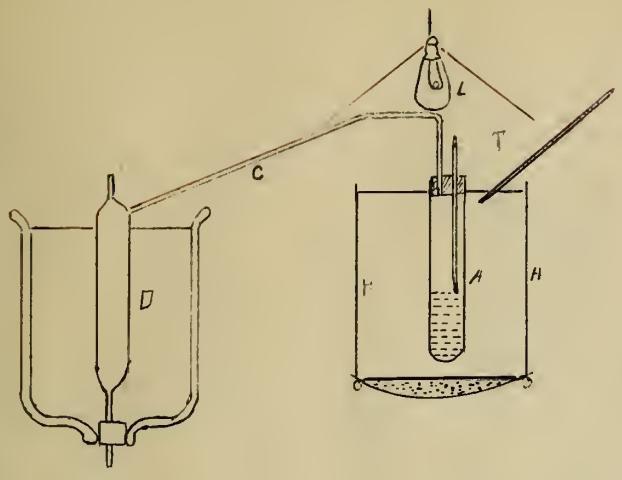



FIGURE I

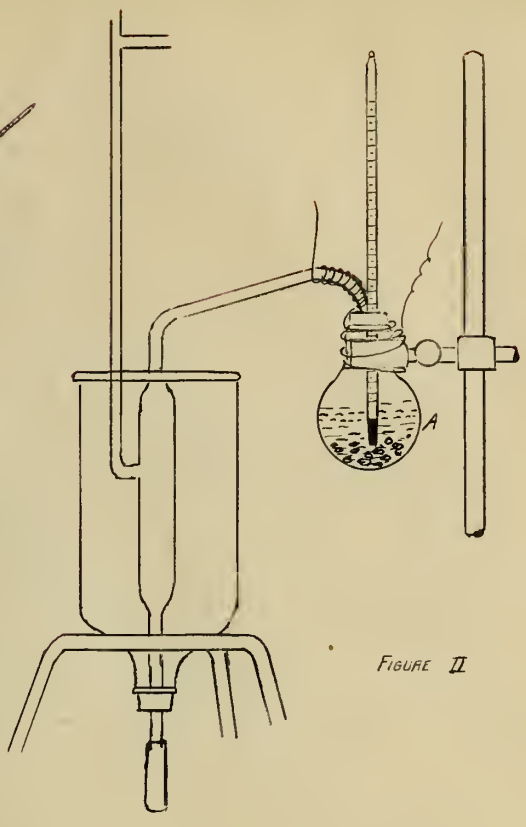



FIGURE II

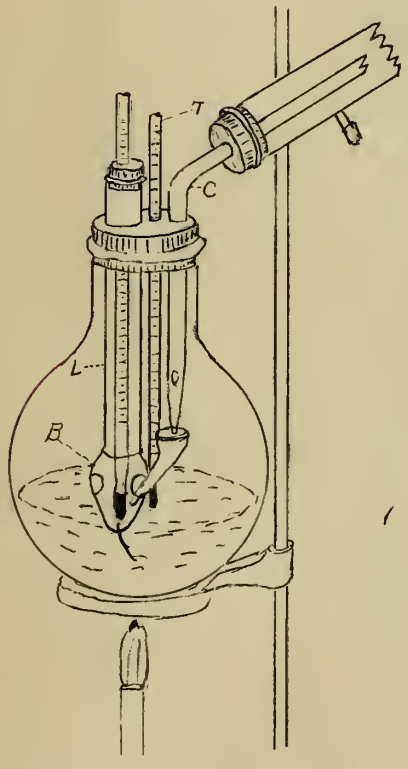



FIGURE III

FIGURE V

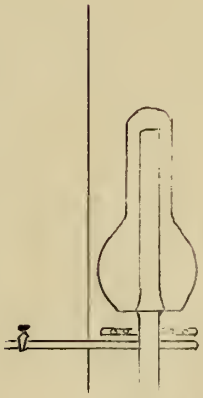


FIGURE IV

FIGURE VII

FIGURE IX

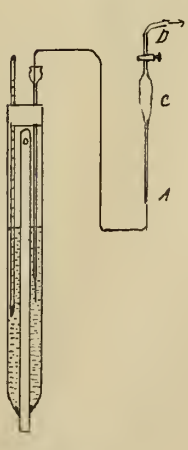



FIGURE VIII

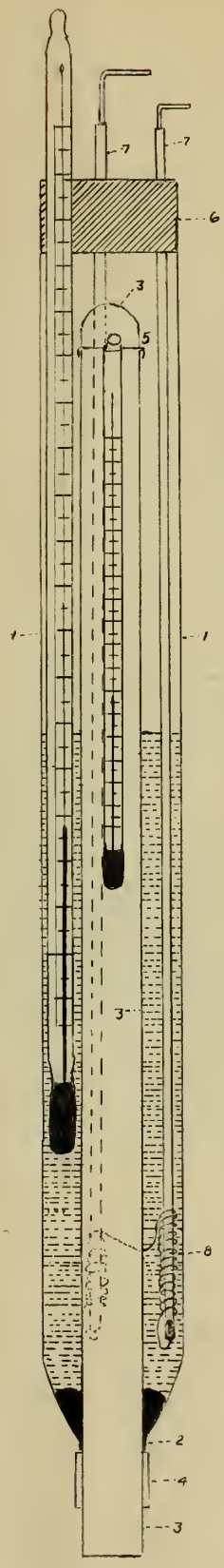
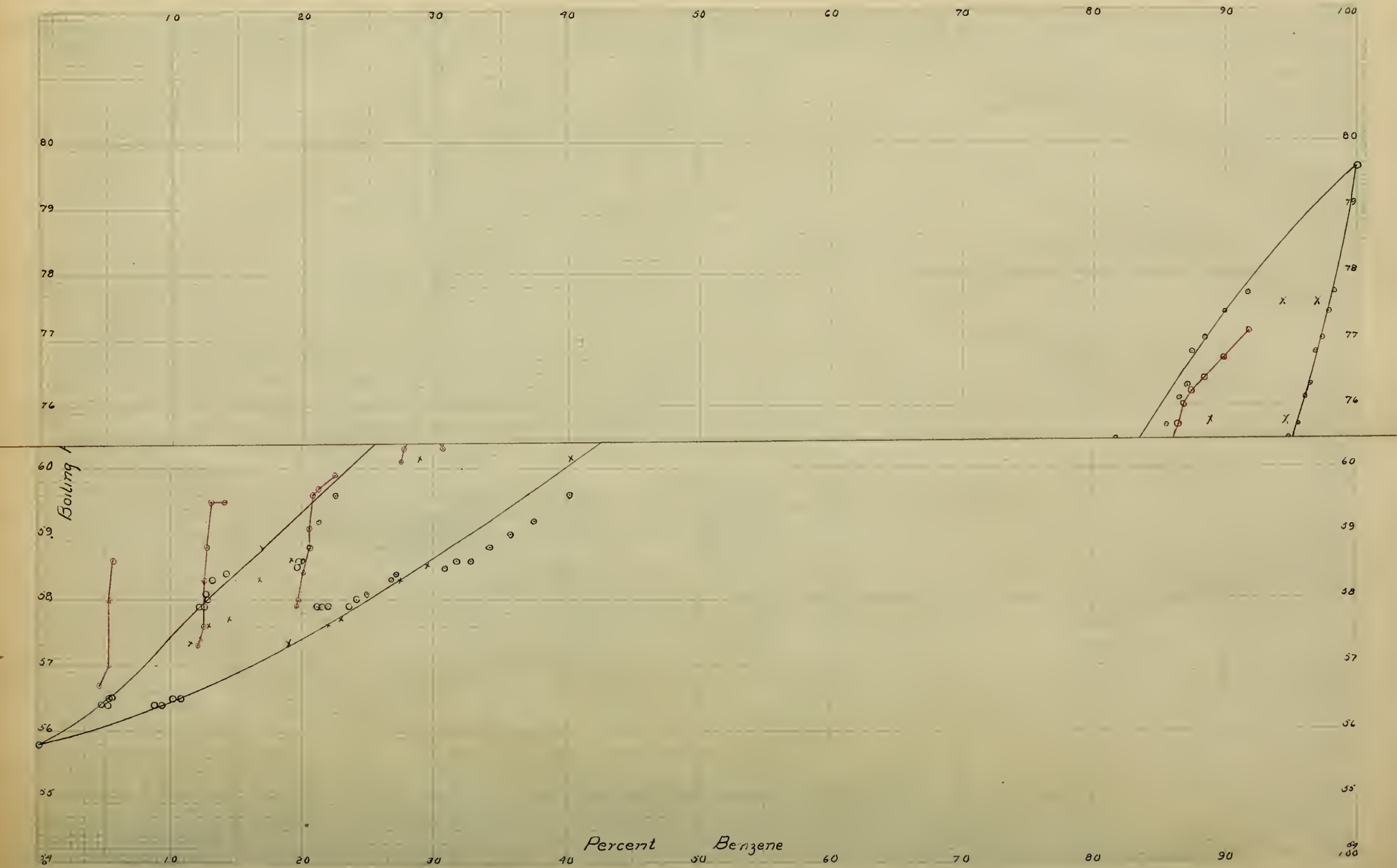



FIGURE VI


Boiling
Percent Benzene

Boiling Point Corrected to 760 mm
Percent Benzene

TABLE I.

| Sample Number | TEMPERATURES | | | | | Index | Composition in per cent benzene | |
|---|---|---|---|---|---|---|---|---|
| | Liquid | Mean Liquid | Mean Liquid corrected for Pressure | Vapor | Mean Vapor | | Liquid & Vapor | Mean Liquid |
| $L_1$ | 56.6 | | | 56.6 | | 1.3688 | 8.7 | |
| $V_2$ | | 56.6 | 56.4 | | 56.7 | 1.3642 | 4.7 | 8.8 |
| $L_2$ | 56.6 | | | 56.7 | | 1.3689 | 8.8 | |
| $V_3$ | | 56.6 | 56.4 | | 57.0 | 1.3648 | 5.3 | 9.4 |
| $L_3$ | 56.6 | | | 57.3 | | 1.3699 | 9.9 | |
| $V_4$ | | 56.7 | 56.5 | | 58.0 | 1.3649 | 5.3 | 10.2 |
| $L_4$ | 56.7 | | | 58.7 | | 1.3708 | 10.4 | |
| $V_5$ | | 56.7 | 56.5 | | 58.6 | 1.3651 | 5.6 | 10.8 |
| $L_5$ | 56.7 | | | 58.5 | | 1.3716 | 11.1 | |

Barometer 746.1

TABLE II.

| Sample Number | TEMPERATURES Liquid | Mean Liquid | Mean Liquid corrected for Pressure | Vapor | Mean Vapor | Index | Composition in per cent. benzene Liquid & Vapor | Mean Liquid |
|---|---|---|---|---|---|---|---|---|
| $L_1$ | 57.8 | | | 57.3 | | 1.3848 | 21.1 | |
| $V_2$ | | 57.8 | 57.9 | | 57.3 | 1.3731 | 12.2 | 21.2 |
| $L_2$ | 57.8 | | | 57.3 | | 1.3849 | 21.2 | |
| $V_3$ | | 57.8 | 57.9 | | 57.4 | 1.3732 | 12.3 | 21.5 |
| $L_3$ | 57.8 | | | 57.5 | | 1.3855 | 21.7 | |
| $V_4$ | | 57.8 | 57.9 | | 57.6 | 1.3734 | 12.5 | 22.0 |
| $L_4$ | 57.8 | | | 57.7 | | 1.3862 | 22.3 | |
| $V_5$ | | 57.9 | 57.9 | | 57.9 | 1.3735 | 12.5 | 23.6 |
| $L_5$ | 57.9 | | | 58.0 | | 1.3895 | 24.8 | |
| $V_6$ | | 57.9 | 58.0 | | 58.3 | 1.3736 | 12.6 | 24.2 |
| $L_6$ | 57.9 | | | 58.5 | | 1.3879 | 23.6 | |
| $V_7$ | | 57.9 | 58.0 | | 58.8 | 1.3738 | 12.7 | 24.0 |
| $L_7$ | 58.0 | | | 59.0 | | 1.3889 | 24.3 | |
| $V_8$ | | 58.0 | 58.1 | | 59.3 | 1.3738 | 12.7 | 25.0 |
| $L_8$ | 58.0 | | | 59.5 | | 1.3906 | 25.6 | |
| $V_9$ | | 58.2 | 58.3 | | 59.5 | 1.3743 | 13.1 | 26.8 |
| $L_9$ | 58.3 | | | 59.5 | | 1.3940 | 28.0 | |
| $V_{10}$ | | 58.4 | 58.4 | | 59.5 | 1.3754 | 14.2 | 27.2 |
| $L_{10}$ | 58.5 | | | 59.5 | | 1.3915 | 26.3 | |

Barometer 738.2

TABLE III.

| Sample Number | TEMPERATURES Liquid | Mean Liquid | Mean Liquid corrected for Pressure | Vapor | Mean Vapor | Index | Composition in per cent. benzene Liquid & Vapor | Mean Liquid |
|---|---|---|---|---|---|---|---|---|
| $L_1$ | 58.4 | | | 57.8 | | 1.3970 | 30.4 | |
| $V_2$ | | 58.4 | 58.5 | | 57.9 | 1.3829 | 19.7 | 30.8 |
| $L_2$ | 58.5 | | | 57.9 | | 1.3981 | 31.3 | |
| $V_3$ | | 58.5 | 58.6 | | 58.0 | 1.3830 | 19.8 | 31.75 |
| $L_3$ | 58.5 | | | 58.1 | | 1.3994 | 32.2 | |
| $V_4$ | | 58.5 | 58.6 | | 58.4 | 1.3833 | 20.1 | 32.9 |
| $L_4$ | 58.6 | | | 58.6 | | 1.4011 | 33.6 | |
| $V_5$ | | 58.7 | 58.8 | | 59.1 | 1.3839 | 20.6 | 34.3 |
| $L_5$ | 58.8 | | | 59.5 | | 1.4031 | 35.0 | |
| $V_6$ | 58. | 58.8 | 59.0 | | 59.6 | 1.3843 | 40.9 | 35.9 |
| $L_6$ | 58.9 | | | 59.7 | | 1.4057 | 36.7 | |
| $V_7$ | | 59.1 | 59.2 | | 59.7 | 1.3850 | 21.3 | 37.7 |
| $L_7$ | 59.2 | | | 59.7 | | 1.4083 | 38.6 | |
| $V_8$ | | 59.4 | 59.6 | | 59.9 | 1.3868 | 22.6 | 40.3 |
| $L_8$ | 59.7 | | | 60.0 | | 1.4130 | 41.9 | |

Barometer 736.9

TABLE IV.

| Sample Number | TEMPERATURES Liquid | Mean Liquid | Mean Liquid corrected for Pressure | Vapor | Mean Vapor | Index | Composition in per cent. benzene: Liquid & Vapor | Mean Liquid |
|---|---|---|---|---|---|---|---|---|
| $L_1$ | 60.6 | | | 60.1 | | 1.4157 | 43.8 | |
| $V_2$ | | 61.2 | 60.8 | | 60.1 | 1.3947 | 27.6 | 44.3 |
| $L_2$ | 60.7 | | | 60.1 | | 1.4170 | 44.8 | |
| $V_3$ | | 61.3 | 60.9 | | 60.1 | 1.3948 | 27.6 | 45.2 |
| $L_3$ | 60.8 | | | 60.1 | | 1.4179 | 45.5 | |
| $V_4$ | | 61.4 | 61.0 | | 60.3 | 1.3951 | 27.8 | 46.0 |
| $L_4$ | 60.9 | | | 60.5 | | 1.4191 | 46.4 | |
| $V_5$ | | 61.5 | 61.1 | | 60.8 | 1.3958 | 29.4 | 46.9 |
| $L_5$ | 61.0 | | | 61.1 | | 1.4204 | 47.3 | |
| $V_6$ | | 61.7 | 61.3 | | 60.3 | 1.3975 | 30.8 | 48.6 |
| $L_6$ | 61.3 | | | 61.5 | | 1.4239 | 49.9 | |
| $V_7$ | | 61.9 | 61.5 | | 61.7 | 1.3980 | 31.2 | 50.7 |
| $L_7$ | 61.5 | | | 61.8 | | 1.4258 | 51.4 | |
| $V_8$ | | 62.3 | 61.9 | | 62.0 | 1.3991 | 32.0 | 52.5 |
| $L_8$ | 62.0 | | | 62.2 | | 1.4291 | 53.5 | |
| $V_9$ | | 62.8 | 62.4 | | 62.4 | 1.4006 | 33.1 | 55.1 |
| $L_9$ | 62.5 | | | 62.5 | | 1.4339 | 56.7 | |
| $V_{10}$ | | 62.8 | 62.4 | | 62.7 | 1.4030 | 34.8 | 58.3 |
| $L_{10}$ | 63.0 | | | 62.8 | | 1.4389 | 59.9 | |

Barometer 749.4

TABLE V.

| Sample Number | TEMPERATURES Liquid | Mean Liquid | Mean Liquid corrected for Pressure | Vapor | Mean Vapor | Index | Composition in per cent. benzene Liquid & Vapor | Mean Liquid |
|---|---|---|---|---|---|---|---|---|
| $L_1$ | 63.4 | | | 62.6 | | 1.4441 | 63.6 | |
| $V_2$ | | 63.6 | 63.8 | | 62.8 | 1.4158 | 43.9 | 64.5 |
| $L_2$ | 63.8 | | | 63.0 | | 1.4466 | 65.3 | |
| $V_3$ | | 64.0 | 64.2 | | 63.1 | 1.4169 | 44.8 | 66.1 |
| $L_3$ | 64.2 | | | 63.2 | | 1.4490 | 66.9 | |
| $V_4$ | | 64.4 | 64.6 | | 63.4 | 1.4178 | 45.4 | 67.9 |
| $L_4$ | 64.7 | | | 63.6 | | 1.4518 | 68.8 | |
| $V_5$ | | 65.0 | 65.2 | | 64.0 | 1.4200 | 47.0 | 70.3 |
| $L_5$ | 65.4 | | | 64.4 | | 1.4560 | 71.7 | |
| $V_6$ | | 66.3 | 66.5 | | 64.6 | 1.4228 | 49.1 | 73.0 |
| $L_6$ | 66.2 | | | 64.8 | | 1.4598 | 74.2 | |
| $V_7$ | | 66.5 | 66.7 | | 64.9 | 1.4250 | 50.6 | 75.5 |
| $L_7$ | 67.0 | | | 64.9 | | 1.4638 | 76.8 | |
| $VV_8$ | | 67.4 | 67.6 | | 65.2 | 1.4276 | 52.4 | 78.1 |
| $L_8$ | 67.8 | | | 65.5 | | 1.4672 | 79.3 | |

Barometer 735.8

TABLE VI.

| Sample Number | TEMPERATURES Liquid | Mean Liquid | Mean Liquid corrected for Pressure | Vapor | Mean Vapor | Index | Composition in per cent. benzene Liquid & vapor | Mean Liquid |
|---|---|---|---|---|---|---|---|---|
| $L_1$ | 66.1 | | | 65.5 | | 1.4599 | 74.3 | |
| $V_2$ | | 66.2 | 66.4 | | 65.8 | 1.4294 | 53.7 | 74.7 |
| $L_2$ | 66.3 | | | 66.0 | | 1.4610 | 75.1 | |
| $V_3$ | | 66.4 | 66.6 | | 66.2 | 1.4299 | 54.0 | 75.4 |
| $L_3$ | 66.5 | | | 66.3 | | 1.4620 | 75.7 | |
| $V_4$ | | 66.7 | 66.8 | | 66.4 | 1.4300 | 54.1 | 76.2 |
| $L_4$ | 66.8 | | | 66.4 | | 1.4633 | 76.7 | |
| $V_5$ | | 67.0 | 67.1 | | 66.6 | 1.4302 | 54.2 | 77.2 |
| $L_5$ | 67.1 | | | 66.7 | | 1.4650 | 77.7 | |
| $V_6$ | | 67.4 | 67.6 | | 66.9 | 1.4320 | 55.4 | 78.4 |
| $L_6$ | 67.7 | | | 67.1 | | 1.4670 | 79.1 | |
| $V_7$ | | 68.0 | 68.2 | | 67.3 | 1.4329 | 56.0 | 79.9 |
| $L_7$ | 68.3 | | | 67.5 | | 1.4692 | 80.6 | |
| $V_8$ | | 68.6 | 68.8 | | 67.6 | 1.4344 | 56.9 | 81.2 |
| $L_8$ | 68.9 | | | 67.6 | | 1.4710 | 81.7 | |
| $V_9$ | | 67.3 | 69.5 | | 67.9 | 1.4373 | 59.0 | 82.8 |
| $L_9$ | 69.7 | | | 68.1 | | 1.4740 | 83.8 | |
| $V_{10}$ | | 70.3 | 70.4 | | 68.4 | 1.4384 | 59.7 | 85.2 |
| $L_{10}$ | 70.8 | | | 68.7 | | 1.4780 | 86.5 | |

Barometer 736.6

TABLE VII.

| Sample Number | TEMPERATURES Liquid | Mean Liquid | Mean Liquid corrected for Pressure | Mean Vapor | Mean Vapor | Index | Composition in per cent. benzene Liquid & Vapor | Mean Liquid |
|---|---|---|---|---|---|---|---|---|
| $L_1$ | 70.7 | | | 69.7 | | 1.4781 | 86.5 | |
| $V_2$ | | 70.9 | 70.9 | | 70.1 | 1.4536 | 70.0 | 87.1 |
| $L_2$ | 71.1 | | | 70.4 | | 1.4797 | 87.6 | |
| $V_3$ | | 71.5 | 71.5 | | 70.8 | 1.4555 | 71.3 | 88.2 |
| $L_3$ | 71.9 | | | 71.1 | | 1.4813 | 88.8 | |
| $V_4$ | | 72.2 | 72.2 | | 71.3 | 1.4579 | 73.0 | 89.5 |
| $L_4$ | 72.5 | | | 71.4 | | 1.4833 | 90.2 | |
| $V_5$ | | 72.9 | 72.9 | | 71.6 | 1.4608 | 74.9 | 90.8 |
| $L_5$ | 73.3 | | | 71.8 | | 1.4851 | 91.3 | |
| $V_6$ | | 73.6 | 73.6 | | 72.5 | | | 92.1 |
| $L_6$ | 74.0 | | | 73.1 | | 1.4873 | 92.8 | |
| $V_7$ | | 74.5 | 74.5 | | 73.5 | 1.4659 | 78.3 | 93.6 |
| $L_7$ | 75.0 | | | 73.8 | | 1.4896 | 94.3 | |
| $V_8$ | | 75.5 | 75.5 | | 74.2 | 1.4707 | 81.5 | 94.6 |
| $L_8$ | 75.9 | | | 74.5 | | 1.4902 | 94.8 | |

Barometer 740.4

TABLE VIII.

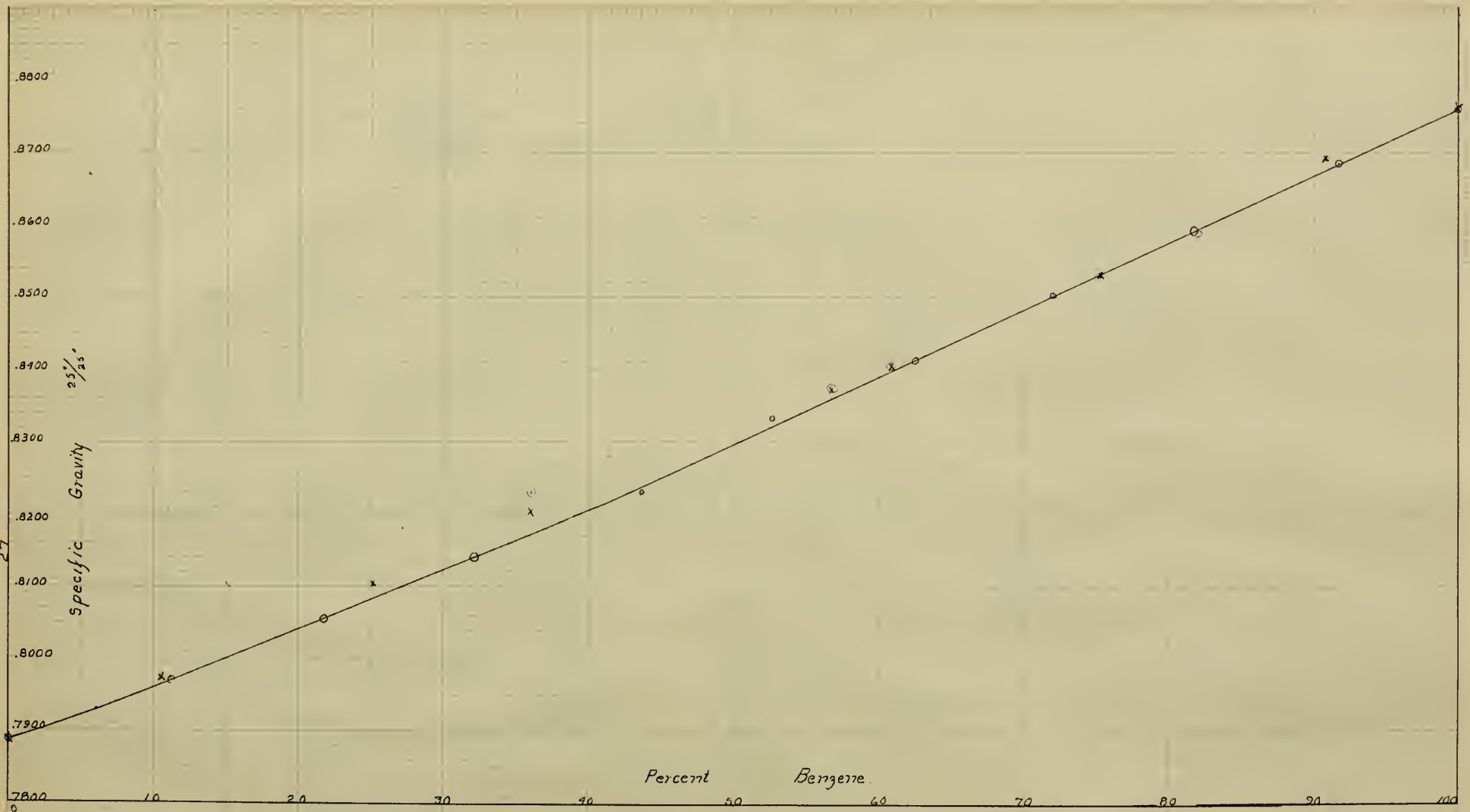
| Sample Number | TEMPERATURES Liquid | Mean Liquid | Mean Liquid corrected for Pressure | Vapor | Mean Vapor | Index | Composition in per cent. benzene: Liquid & Vapor | Mean Liquid |
|---|---|---|---|---|---|---|---|---|
| $L_1$ | 75.6 | | | 75.0 | | 1.4906 | 95.0 | |
| $V_2$ | | 75.9 | 75.7 | | 75.2 | 1.4766 | 85.4 | 95.3 |
| $L_2$ | 76.1 | | | 75.4 | | 1.4914 | 95.6 | |
| $V_3$ | | 76.3 | 76.1 | | 75.7 | 1.4779 | 86.4 | 95.9 |
| $L_3$ | 76.4 | | | 75.9 | | 1.4921 | 96.2 | |
| $V_4$ | | 76.5 | 76.3 | | 76.0 | 1.4784 | 86.7 | 96.3 |
| $L_4$ | 76.6 | | | 76.1 | | 1.4926 | 96.4 | |
| $V_5$ | | 76.8 | 76.6 | | 76.2 | 1.4791 | 87.3 | 96.7 |
| $L_5$ | 76.9 | | | 76.3 | | 1.4934 | 97.0 | |
| $V_6$ | | 77.1 | 77.0 | | 76.4 | 1.4807 | 88.3 | 97.2 |
| $L_6$ | 77.3 | | | 76.5 | | 1.4940 | 97.4 | |
| $V_7$ | | 77.5 | 77.4 | | 76.7 | 1.4830 | 89.8 | 97.7 |
| $L_7$ | 77.7 | | | 76.9 | | 1.4948 | 97.9 | |
| $V_8$ | | 77.8 | 77.7 | | 77.1 | 1.4856 | 91.7 | 98.1 |
| $L_8$ | 78.0 | | | 77.3 | | 1.4953 | 98.3 | |

Barometer 742.5

TABLE IX.

Relation of Composition to Specific Gravity in Mixtures of Benzene and Acetone at 25°/25° C.

| Per cent. Benzene | Per cent. Acetone | Specific Gravity 25°/25° |
|---|---|---|
| 11.2 | 88.8 | .7969 |
| 21.8 | 78.2 | .8053 |
| 32.2 | 67.8 | .8140 |
| 43.6 | 57.4 | .8230 |
| 52.7 | 47.3 | .8331 |
| 62.5 | 37.5 | .8413 |
| 72.0 | 28.0 | .8501 |
| 81.7 | 18.3 | .8590 |
| 91.7 | 8.3 | .8683 |

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COMPOSITION SPECIFIC GRAVITY CURVE FOR MIXTURES OF BENZENE AND ACETONE.

TABLE X.

Relation of Composition to Index of Refraction in Mixtures of Benzene and Acetone at 25° C.

| Per cent. Acetone | Per cent. Benzene | Index of Refraction. |
|---|---|---|
| 0.0 | 100.0 | 1.4977 |
| 8.3 | 91.7 | 1.4847 |
| 8.9 | 91.1 | 1.4839 |
| 18.3 | 81.7 | 1.4698 |
| 18.4 | 81.6 | 1.4691 |
| 27.9 | 72.1 | 1.4550 |
| 28.0 | 72.0 | 1.4554 |
| 37.5 | 62.5 | 1.4412 |
| 37.5 | 62.5 | 1.4409 |
| 47.3 | 52.7 | 1.4268 |
| 47.3 | 52.7 | 1.4269 |
| 57.4 | 42.6 | 1.4125 |
| 57.4 | 42.6 | 1.4130 |
| 67.8 | 32.2 | 1.3980 |
| 67.8 | 32.2 | 1.3981 |
| 78.2 | 21.8 | 1.3842 |
| 82.1 | 17.9 | 1.3817 |
| 85.4 | 14.6 | 1.3721 |
| 88.8 | 11.2 | 1.3710 |
| 100.0 | 0.0 | 1.3569 |

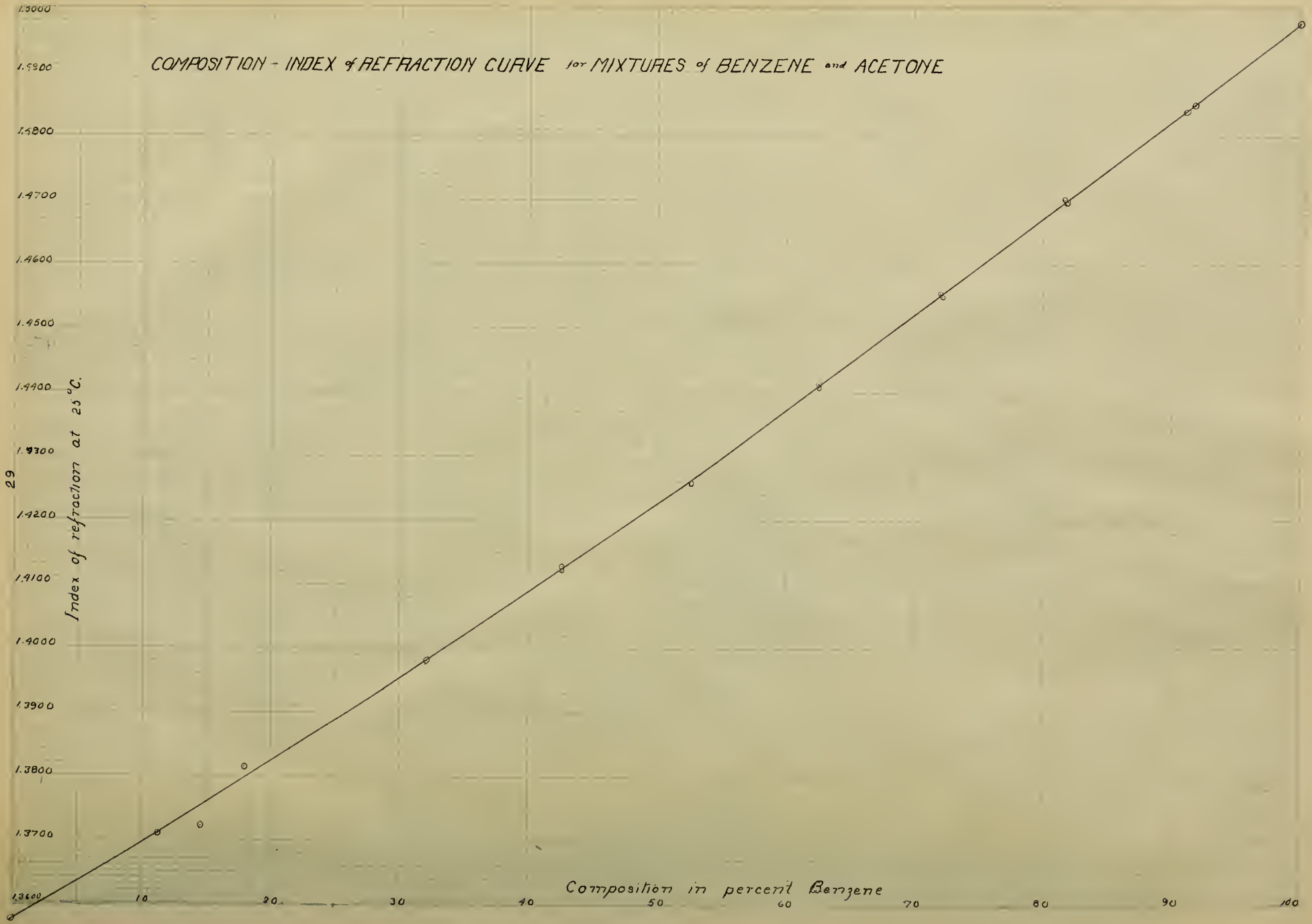
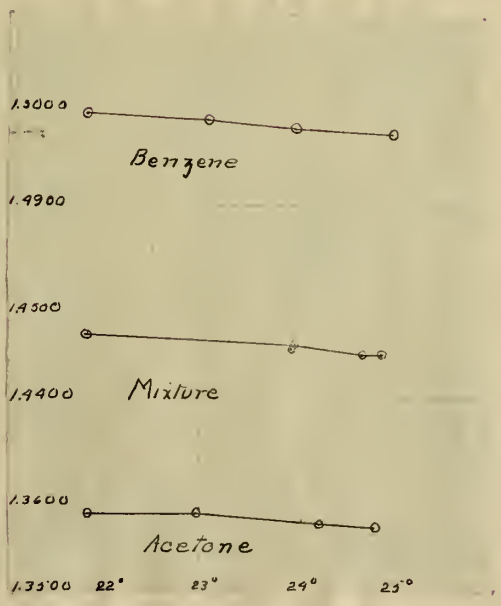

COMPOSITION - INDEX of REFRACTION CURVE for MIXTURES of BENZENE and ACETONE
1.5000
1.4900
1.4800
1.4700
1.4600
1.4500
1.4400
1.4300
1.4200
1.4100
1.4000
1.3900
1.3800
1.3700
1.3600
Index of refraction at 25°C.
10
20
30
40
50
60
70
80
90
100
Composition in percent Benzene

TABLE XI.

Effect of Variation of Temperature upon Index of Refraction.

| Acetone | | Mixture | | Benzene | |
|---|---|---|---|---|---|
| Temp. | Index | Temp. | Index | Temp. | Index |
| 21.8 | 1.3580 | 21.8 | 1.4998 | 21.8 | 1.4465 |
| 23.0 | 1.3580 | 23.1 | 1.4990 | | |
| 24.1 | 1.3569 | 24.0 | 1.4980 | 24.0 | 1.4452 |
| 24.8 | 1.3568 | 25.0 | 1.4977 | 24.9 | 1.4445 |



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